HIGH-FREQUENCY SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a high-frequency semiconductor device, and more particularly, to an improvement in thermal stability of a multi-finger heterojunction bipolar transistor.

2. Description of the Related Art

Miniaturization is an important factor in promoting proliferation of portable terminals such as portable cellular phones. A high-output power amplifier has become a key part of a recent portable terminal.

A heterojunction bipolar transistor (hereinafter simply called "HBT") has a high current gain β. A GaAs-based HBT having an emitter made of AlGaAs and a base made of GaAs is characterized by its high speed and is widely used for a high-output power amplifier of a portable cellular phone.

In order to attain a high output, HBTs must be arranged in shunt with each other, to there by form a multi-finger configuration. An HBT having such a multi-finger configuration will hereinafter be referred to as a "multi-finger HBT," and individual HBTs constituting the multi-finger HBT will be called "basic HBTs."

FIG. **8** is a plan view showing one of basic HBTs constituting a conventional high-output power amplifier.

In connection with FIG. **8**, reference numeral **100** designates a basic HBT; **102** designates a collector layer; **104** designates a collector electrode; **106** designates a base layer; **108** designates a base electrode; **110** designates an emitter layer; and **112** designates an emitter electrode.

In a case where a multi-finger HBT is activated, the current gain β decreases with temperature. For this reason, in contrast with a homojunction bipolar transistor (for example, an Si bipolar transistor) having a current gain β increasing with temperature, the multi-finger HBT is resistant to thermal runaway.

However, it has already been reported that, because thermal nonuniformity arises among basic HBTs **100** within the multi-finger HBT, concentrated flow of current to a certain basic HBT **100** arises, thereby inducing a rapid change in an operating current. For instance, there is a report on failure arising for this reason (IEEE Transactions on Electronic Devices, Vol. 43, No. 2, February 1996, pp. 220 to 227).

Effective countermeasure against such a rapid change in an operating current is a reduction in thermal resistance of the basic HBT **100**.

Thermal resistance ΘTH is defined as $\Theta TH=\Delta Tj/\Delta P$, where Tj is junction temperature and P is power.

FIG. **9** is a plan view showing a basic HBT constituting another conventional high-output power amplifier.

In connection with FIG. **9**, reference numeral **120** designates a basic HBT consisting of two emitters; **110***a* and **110***b* designate split emitter layers constituting an emitter layer **110** of the basic HBT **120**; and **112***a* and **112***b* are split emitter electrodes constituting an emitter electrode of the basic HBT **120**.

FIG. **10** is a cross-sectional view taken along line X—X shown in FIG. **9**.

As shown in FIG. **10**, reference numeral **122** designates a GaAs substrate.

The basic HBT **120** shown in FIGS. **9** and **10** is formed from two emitters in order to reduce the thermal resistance ΘTH.

Two types of multi-finger HBTs are prepared: namely, a multi-finger HBT which has a single emitter **112** provided between collectors **104**, as does the basic HBT **100**; and a multi-finger HBT which has two emitters **112** provided between collectors **104**, as does the basic HBT **120**. In order to examine occurrence of thermal nonuniformity, an I–V characteristic obtained when a collector voltage Vc is changed while a base current is maintained constant is obtained as a base current parameter.

FIG. **11** is a graph showing the I–V characteristic of a multi-finger HBT using the basic HBT **100** made of a single emitter. FIG. **12** is a graph showing the I–V characteristic of a multi-finger HBT using the basic HBT **120** made of two emitters.

As shown in FIGS. **11** and **12**, a gradual reduction arises in an electric current within a range of small power dissipation; i.e., a range of Vc<6-volts or thereabouts, because negative feedback is applied from a power source to the HBTs **100** and **120** for reasons of temperature characteristics of current gain β of the basis HBT. In terms of such a characteristic, no difference is present between the multi-finger HBT using the basic HBT **100** made of a single emitter and the multi-finger HBT using the basic HBT **120** made of two emitters.

However, within a range of large power dissipation, i.e., a range of Vc=6V or greater, the basic HBT **100** comprising a single emitter causes breakdown of a collector current Ic at a voltage Vc lower than that at which the basic HBT **120** comprising two emitters causes breakdown of the collector current Ic. In other words, the basic HBT **100** causes breakdown of the collector current Ic in a range of power dissipation lower than that in which the basic HBT **120** causes breakdown of the collector current Ic. Broken lines **A1** shown in FIG. **11** designate a boundary within which concentration of electric current onto the basic HBT **100** arises under the foregoing conditions. Broken lines **A2** shown in FIG. **12** designate a boundary within which concentration of electric current the basic HBT **120** arises under the foregoing conditions. The broken lines **A2** shown in FIG. **12** are clearly shifted toward a higher Vc range than the broken lines Al shown in FIG. **11**.

Separating an emitter to be provided between collectors into a plurality of pieces is effective for preventing occurrence of thermal nonuniformity in basic HBTs.

However, if an emitter has a plurality of parts, an area for separation must be ensured between the emitter electrodes **112***a* and **112***b*. The area of a junction between the base layer **106** and the collector layer **102** becomes large, thereby increasing the capacitance of a p-n junction. An increase in the capacitance of the p-n junction deteriorates high-frequency characteristics of a semiconductor device, thereby resulting in a decrease in gain.

Japanese Patent Application Laid-Open No. Hei. 11-102916 describes a bipolar transistor which comprises a plurality of single emitters and in which first stages of a multi-stage amplifier are connected in shunt with each other. Further, there is described proper use of a bipolar transistor of single emitter structure and a bipolar transistor of multi-emitter structure, as appropriate. However, none of the transistors correspond to a heterojunction silicon transistor.

SUMMARY OF THE INVENTION

The present invention has been conceived to overcome such a drawback and is aimed at providing a high-frequency